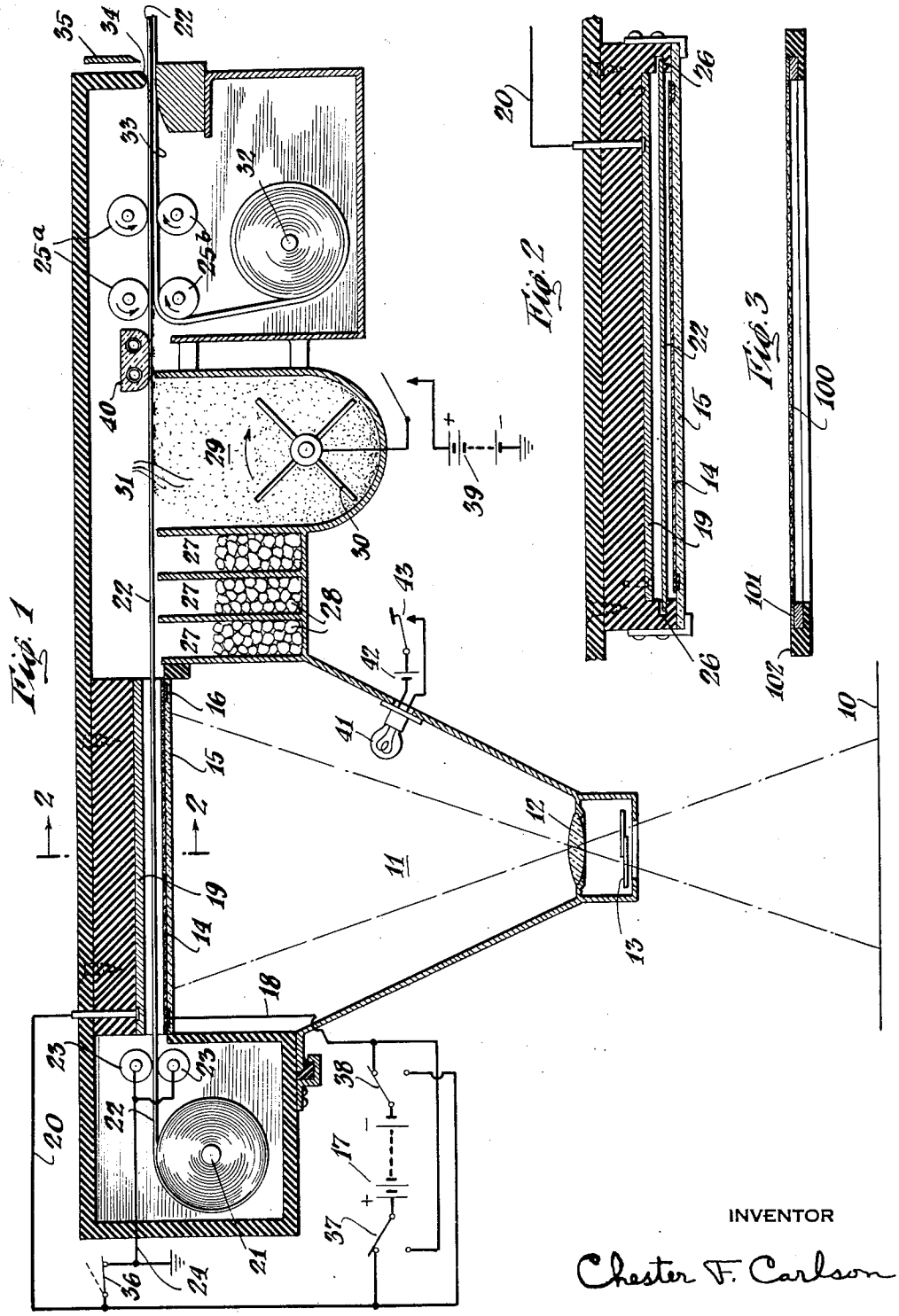
Nov. 19, 1940. C. F. CARLSON 2,221,776

ELECTRON PHOTOGRAPHY

Filed Sept. 8, 1938 2 Sheets-Sheet 1



INVENTOR

Chester F. Carlson

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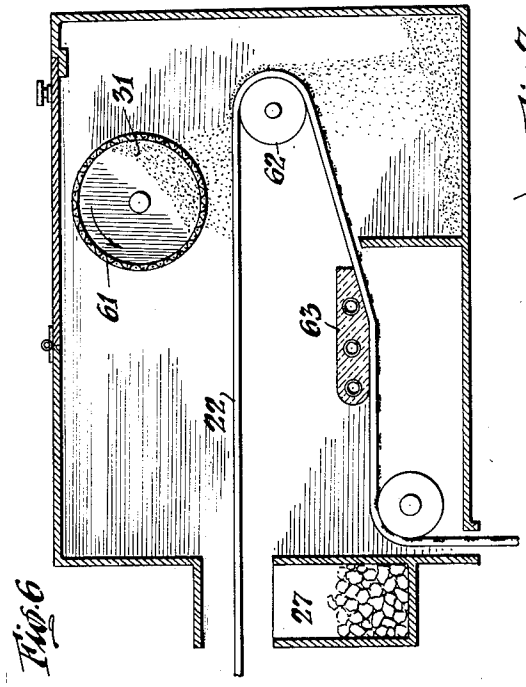

Fig. 6

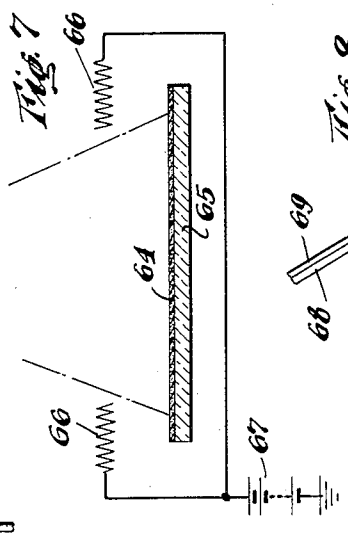

Fig. 7

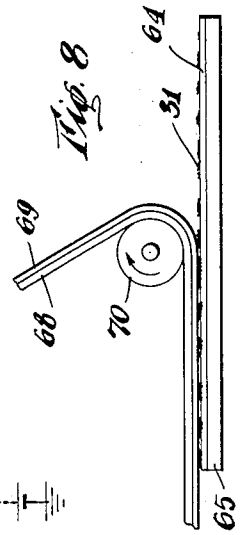

Fig. 8

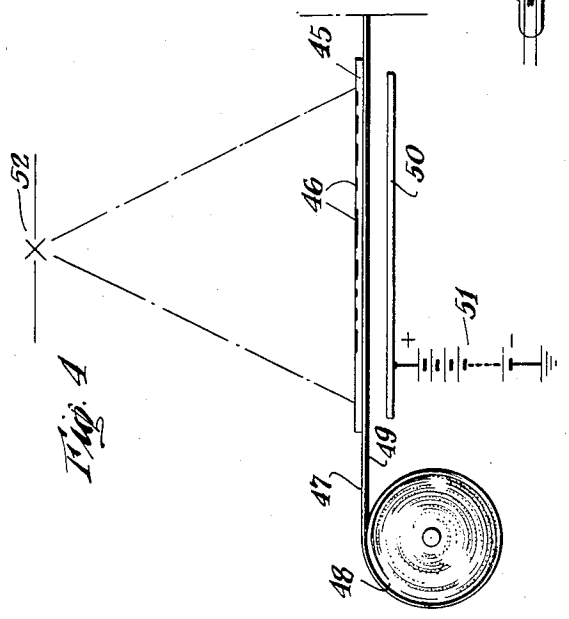

Fig. 4

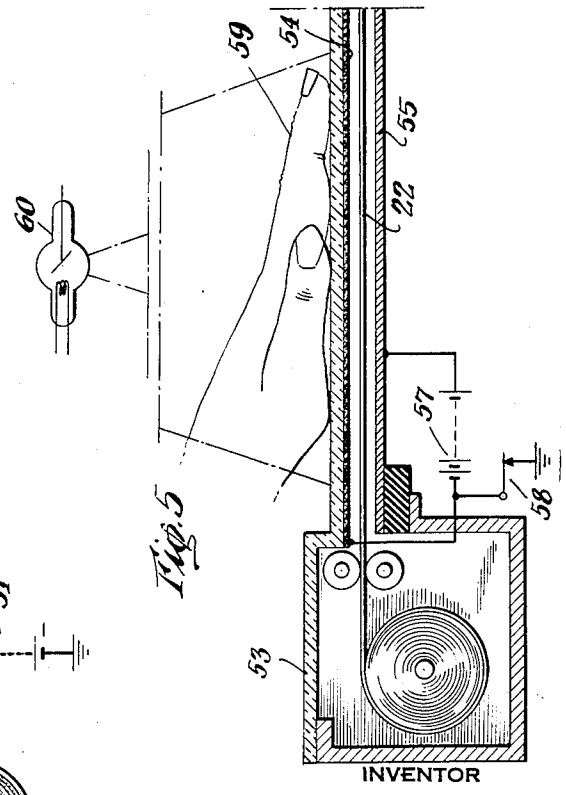

Fig. 5

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UNITED STATES PATENT OFFICE

2,221,776

ELECTRON PHOTOGRAPHY

Chester F. Carlson, Jackson Heights, N. Y.

Application September 8, 1938, Serial No. 228,905

11 Claims. (Cl. 95—5)

This invention relates to photography.

An object of the invention is to improve photographic processes and devices.

Other objects of the invention will be apparent from the following description and accompanying drawings taken in connection with the appended claims.

The invention comprises the features of construction, combination of elements, arrangement of parts, and methods of manufacture and operation referred to above or which will be brought out and exemplified in the disclosure hereinafter set forth, including the illustrations in the drawings.

In the drawings:

Figure 1 is a sectional elevation of an electrophotographic device;

Figure 2 is a section on the line 2—2 of Figure 1;

Figure 3 shows a modified part;

Figure 4 shows part of a modified device suitable for contact printing;

Figure 5 illustrates part of an X-ray electrophoto arrangement;

Figure 6 shows a modified arrangement for developing the electric latent image; and

Figures 7 and 8 illustrate another photographic procedure.

My invention contemplates the use of a photoemissive material, that is, material which emits electrons when exposed to radiation such as light, ultra-violet rays, X-rays or the like. According to the invention a layer or surface having photoemissive qualities is exposed to radiation (having a desired image or pattern, for example) to produce a corresponding emission of electrons in the areas receiving the radiation. The electric charge pattern (electrostatic latent image) thus produced on the photoemissive layer or on an adjacent layer of insulation is then developed or rendered visible by depositing a suitable material, such as powder, under influence of the charge pattern.

This may preferably be done automatically immediately after the electric latent image is produced and I have devised certain automatic devices for depositing a finely divided material to develop the image and for fixing the material after deposition. My invention therefore provides an automatic photographing machine comprising a single piece of apparatus for producing a finished print.

While a preferred embodiment of the invention is described herein, it is contemplated that considerable variation may be made in the method of procedure and the construction of parts without departing from the spirit of the invention. In the following description and in the claims, parts will be identified by specific names for convenience, but they are intended to be as generic in their application to similar parts as the art will permit.

Referring to the drawings, Figure 1 shows a device particularly adapted for making photographic reproductions of printed or typewritten matter, drawings, pictures and the like although it may also be used in some cases for general photography. The sheet 10 bearing the printing or drawing to be reproduced is laid on a table and the apparatus is suitably suspended above it with camera portion 11 disposed directly over the sheet 10. Lens 12 is positioned in the lower end of the camera so as to focus the image of the sheet 10 on a photo-electric layer 14 deposited upon a sheet 15 of transparent material supported in the upper part of the camera. Shutter 13 controls the entry of light into the camera. The photoelectric layer 14 is preferably conductive or provided with a contiguous conductor such as a transparent thin metal film deposited upon the sheet 15 before the photoelectric material, or a fine wire screen secured to the surface of sheet 15. A current collecting margin strip 16 of highly conductive material is also provided near the edges of sheet 15 and this is connected to a battery 17 by an insulated conductor 18 and switch 38.

A plane metal electrode 19 is also supported within the camera behind photo-emissive layer 14 and parallel to it. Electrode 19 is connected to the opposite terminal of battery 17 by conductor 20 and switch 37. Battery 17 is a high voltage battery, preferably above 1000 volts or even several thousand volts although the voltage should not be sufficient to start or to maintain a discharge between the surfaces of layers 14 and 19, other than that which is incidental to the photoelectric effect.

A spool or mandrel 21, mounted at the left end of the back part of the camera (as seen in Figure 1) carries a roll of sheet insulating material 22 upon which the photographs are to be produced.

Sheet 22 is of material of high insulating value under the conditions present in the camera and is transparent or translucent. Suitable materials are unplasticized and dehydrated Cellophane, cellulose acetate, translucent paper, transparent sheet resins, polystyrene sheet, paper or Cellophane impregnated with polystyrene, ethyl cel-

lulose sheet, Celluloid or the like. The end of the sheet 22, as it is unrolled from the spool 21 passes between two smooth metal rollers 23 which are grounded through conductor 24. These rollers serve to remove any electric charge accidentally present on the surface of the sheet 22 as it leaves the roll.

The rolls 23 are positioned to hold the sheet 22 in a plane approximately mid-way between layers 14 and 19. The sheet 22 passes between layers 14 and 19 without touching them and passes between rolls 25 near the right end of the back of the camera (as seen in Figure 1). The sheet is further supported in proper position by guide slots 26 along the two sides of the plates as illustrated in the section shown in Figure 2. This figure also shows how plates 14 and 19 are mounted. Spool 21 is free to rotate but has a friction brake (not shown) to apply a tension to sheet 22. Rolls 25a and 25b are all geared together and are driven by a hand crank or an electric motor whenever it is desired to move the sheet 22 ahead.

A series of chambers 27, adjacent the camera chamber 11, contain a hygroscopic material 28, such as calcium chloride, to maintain a dry atmosphere in the camera. These chambers also help to keep dust out of camera parts.

A dusting chamber 29 is also disposed beneath the sheet 22 and has its open upper end closely adjacent the under surface of the sheet. A rotary vane wheel or propeller 30 is supported within the chamber and connected with a drive motor to rotate it when desired. It may be geared to rollers 25 so as to rotate whenever they are pulling sheet 22 ahead. Chamber 29 contains a charge of very fine powder or dust 31 for application to the sheet 22, as will be described. The powder may be finely powdered dye, pigment, carbon or other black or colored substance or in some cases a white powder such as zinc oxide, titanium dioxide or lycopodium. Likewise mixtures of powders such as a mixture of finely powdered sulfur and finely powdered minimum may be used.

A spool 32 is mounted adjacent rolls 25b and carries a roll of sheet material 33 of approximately the same width as sheet 22. Sheet 33 is led up over rolls 25b so as to be rolled against sheet 22 and be carried along with it to the end of the camera where the two sheets emerge through slit 34 and may be cut off in any desired length by paper knife 35. Sheet 33 may be paper or other similar material. If the powder 31 is black or colored the sheet 33 may preferably be white while if the powder is white or light-colored the sheet can be black or darkly colored.

Either sheet 22 or sheet 33 (or both) is provided with a surface coating of thermosoftening adhesive on the side which comes in contact with the other sheet. Such material may be, for example, a resin such as shellac or rosin, one of the various thermosoftening synthetic resins, rubber compounds, such as rubber hydrochloride, a gum or a wax. If used on sheet 22 it should form a smooth, non-tacky and preferably glossy surface. Rolls 25 are provided with internal electric heating coils which soften the coating as the sheets pass between the rolls thereby causing the sheets to adhere together after they emerge from the rolls.

Switch 36 is arranged to connect conductor 26 to ground when it is closed. Switches 37 and 38 connect the terminals of battery 17 to conductors 18 and 20. With the three switches in the positions shown in Figure 1 plate 19 is connected to the positive terminal of the battery and to ground and photoelectric layer 14 to the negative terminal.

A photograph is produced by the above-described device in the following manner. Shutter 13 is opened and lens 12 focuses the image of sheet 10 onto the photoelectric layer 14. The areas of layer 14 illuminated by the light areas of the image will emit electrons into the adjacent air space between layer 14 and sheet 22. The areas corresponding to the dark parts of the image will be only poorly illuminated or will receive practically no light at all and hence will emit fewer electrons per unit area, or practically none.

The layers 14 and 19 being connected to opposite terminals of the high voltage source are oppositely charged and an intense electric field exists between them tending to draw any free electrons rapidly toward sheet 22. Although electrons will be emitted from layer 14 at all angles the field is strong enough to draw all the emitted electrons onto the surface of sheet 22, which is closely spaced from layer 14, before there is any substantial spreading of the electrons away from their points of origin. Any slight ionization of the air by the stream of electrons will be insufficient to interfere materially with the electron deposition.

The shutter 13 is kept open for sufficient length of time to allow the emitted electrons to build up a considerable electric charge on sheet 22 in the form of an electrostatic latent image or charge image.

As soon as the charge image is formed, rollers 25 are rotated to draw sheet 22 toward the right (as seen in Figure 1) and vane wheel 30 is rotated to bring the powder particles 31 into suspension in the air of chamber 29. As the charged surface of sheet 22 is drawn over chamber 29 the particles are attracted to the surface of the sheet by the charges and adhere to it where the charge density is sufficient, thereby producing a pattern corresponding to the electrostatic latent image. Deposition of the particles is facilitated, if desired, by connecting vane wheel 30 to the positive terminal of a high voltage battery 39 to impart positive charges to the particles.

As sheet 22 proceeds past chamber 29, therefore, it picks up powder particles which develop the electric latent image and render it visible. The sheet 22 then passes between heated rollers 25a and 25b in contact with sheet 33 and the two sheets are stuck together by the thermosoftening adhesive on the surface of one or both. When sheet 22 carries the thermosoftening surface it may be preferable to preset the powder in the surface of the sheet by passing the sheet adjacent a heating element 40 before it comes in contact with sheet 33. In some cases sheet 33 may be dispensed with.

The finished prints emerge through slot 34 and are cut off by knife 35.

According to a modification in the above described apparatus the plate 19 is provided with a surface of photoemissive material and layer 14 is merely a transparent metal film electrode or a fine wire screen. In operation the switches 37 and 38 are reversed to connect layer 19 to the negative and layer 14 to the positive terminal of the high voltage source 17. The image is focused by lens 12 onto the surface of layer 19 and the electrostatic latent image is built up on the

upper surface of transparent sheet 22. In developing the image the charges attract the powder particles through dielectric layer 22, the powder being deposited on the under surface of the sheet as before.

Figure 3 shows a fine wire screen 100 stretched on a metal frame 101 supported in an insulating frame 102. This screen may be used in place of plate 15 and its surface layer in the arrangement just described. Likewise, if screen 100 is of photoelectric metal or has a coating of photoelectric material it may be used as the photoemissive layer in the arrangement first described or in arrangements to be subsequently mentioned.

With further reference to the nature of the photoemissive layer, this will depend upon the wave length of the radiation to be recorded. The composition must, of course, be capable of exposure to air for at least a short time without destroying its photoelectric properties. One series of compounds which are suitable are the Lenard phosphors. For radiation in the blue-violet part of the visible spectrum and in the near ultra-violet the preferred material is the phosphor usually designated as Ca Bi S. This consists essentially of pure calcium sulfide to which a flux and a trace of bismuth have ben added and the whole fused together. With such a material the usual sources of light (containing the effective wave lengths) and lens systems can be used to advantage. The phosphor may preferably be deposited in a very thin layer 14 on top of a thin transparent metal film previously deposited on transparent plate 15. Or it may be held in the interstices of a very fine wire screen secured to the surface of plate 15. In the modification described the phosphor layer may be deposited on plate 19. It will be appreciated that in my invention the photoelectric effect of the phosphors are used, and not the fluorescence which is usually associated with the use of these materials. In fact, the fluorescent excitation of the phosphors appears to diminish the photoelectric emission. To overcome this I provide a small infra-red lamp 41 within the camera chamber 11, connected to battery 42 through switch 43. The infra-red light has a quenching action on the fluorescence. By energizing lamp 41 during exposure of the phosphor layer its photoelectric activity is maintained throughout the exposure period. The lamp is limited to infra-red radiation suitable for quenching the fluorescence and emits none of the shorter wave lengths which produce photoemission.

Other photoelectric materials may be used in carrying out the invention where they possess photoemissive properties at the wave lengths desired to be recorded. For ultra-violet radiation, for example, freshly prepared metal surfaces may be used, such as aluminum, silver, gold, copper etc. Also, non-metals such as anthracene, carbon (soot), copper oxide, copper or lead sulfide, cuprous chloride or shellac having photoelectric properties can be used for ultra-violet. The materials can be used in the form of thin deposited layers, pressed powders or in other suitable forms.

For X-rays many of the photoelectric materials already mentioned are suitable, including most of the metals.

In some cases printing, drawings, typewriting and the like may be reproduced by a contact printing process in which the original is placed adjacent the photoelectric layer and illuminated so as to throw the shadow of the printing or drawing onto the photoelectric layer. Figure 4 shows an original sheet 45 of transparent material carrying indicia 46 to be reproduced. Sheet 45 is placed adjacent to or in contact with a layer of sheet insulating material 47 unrolled from roll 48. Sheet material 47, such as translucent paper or transparent regenerated sheet cellulose carries a thin layer 49 on its under surface of photoemissive material. A metal plate electrode 50 is spaced from this surface and is maintained at a high positive voltage by battery 51. The superposed sheets are illuminated from above by a suitable source of radiation such as arc 52. The parts of the photoelectric layer unprotected by the indicia will emit electrons to plate 50 thereby leaving the surface of sheet 47 with a positive charge distributed over the unshaded areas. The positive latent charge image is developed by dusting as heretofore described.

This method has the advantage of requiring no lenses which cut off part of the ultra-violet spectrum. Hence photoelectric materials which are sensitive only to the shorter ultra-violet waves can be used. For example layer 49 may be a layer of shellac or other resin which is photoelectrically active when illuminated by short ultra violet. Also very thin layers of metals which are photoelectrically active in this region may be used, the metal being deposited in small discrete areas to prevent lateral conductivity in the layer. The "contact" printing process can also be used with the electrode arrangements of Figure 1, by replacing the lens system by a source of radiation and placing the original to be copied against plate 15.

Figure 5 shows an arrangement for making X-ray shadowgraphs utilizing the invention. The top of the apparatus comprises a plate of insulating material 53 carrying a thin layer 54 of material which emits electrons when exposed to X-rays. Metal plate 55 is spaced slightly below layer 54 and insulating sheet 22 passes between the two. Layer 54 is connected to the negative terminal of battery 57 and plate 55 to its positive terminal. The negative terminal may preferably be grounded by switch 58.

The subject 59 to be X-rayed is laid on plate 53 and X-ray tube 60 is positioned above it. The electrons ejected from layer 54 by the X-rays are drawn to sheet 22 forming an electrostatic latent image thereon, which is developed as already described.

In Figure 6 is shown a modified powder deposition apparatus in which a rotating tube 61 of very fine wire screen, silk cloth or the like is positioned above the path of sheet 22 and contains a charge of powder 31 to be deposited on it. The sheet then passes around insulating roller 62 whereupon excess powder not held onto the sheet by the electric charges falls off. The sheet then passes in contact with an electrically heated plate 63 to permanently fix the adherent powder to the sheet. In this arrangement the surface of sheet 22 may be of heat softenable material or the powder itself may be capable of softening by heat. Finely powdered rosin carrying a dye or lampblack incorporated therein is suitable. It is preferred for this arrangement that the electric latent image be formed on the powder-contacting surface of sheet 22, but in some cases, especially where sheet 22 is thin, the charges will act with sufficient force through the sheet to attract the powder. It will be noted that in this arrangement no extra sheet is used in contact with sheet 22.

Figures 7 and 8 illustrate diagrammatically another method which can be used. According to this method the photoelectric material 64 is of an insulating variety and is coated on insulating plate 65. It is illuminated with the image as shown in Figure 7 with collecting grids 66 positioned adjacent the surface to collect the ejected electrons, the grids being charged positively by battery 67. A positive charge latent image is thereby formed on the surface of layer 64. The surface is dusted by sprinkling with powder and shaking off the excess. The dust image is then transferred to a sheet 68 having a slightly tacky surface 69 by rolling the sheet against the plate with soft rubber roller 70.

In the description and drawings the source of high voltage has been indicated as a battery. However, other suitable means of obtaining a high voltage charge are also contemplated as coming within the scope of the invention. For example, various types of electrostatic generators can be used such as the Van de Graaf generator using a rapidly moving silk ribbon belt to carry the charges. Also high voltage power packs using transformer and rectifier may be used. It will be appreciated that almost no current is used in the photographic process and hence only a very minute current capacity is required of the voltage source.

In addition to the powder deposition methods described it is also possible to develop the picture by producing a fine mist of ink with an atomizer, the ink droplets being attracted to the charged areas of the insulating sheet where they deposit and produce the visible picture.

The present invention, in addition to being applicable to general photography and for the reproduction of printing, typewritten matter and drawings, is suitable for graph work wherein a point of light is focused on the photoelectric layer as the insulating sheet travels by, and the graph thus traced is promptly rendered visible by the powder development.

It will also be appreciated that the different parts of the various apparatus described can be combined in different ways, the special combinations illustrated being examples of only a few of the suggested combinations. It will likewise be recognized that any of the well known types of optical systems and camera arrangements, as well as projecting systems for X-rays, ultra-violet radiation and the like can be used to project the image desired upon the photoelectric layer.

This application is a continuation-in-part of my co-pending application, Serial Number 169,630, filed Oct. 18, 1937.

While the present invention, as to its objects and advantages, has been described herein as carried out in specific embodiments thereof, it is not desired to be limited thereby but it is intended to cover the invention broadly within the spirit and scope of the appended claims.

What is claimed is:

1. A device for photography comprising a layer of photoemissive material, a conductive layer in spaced parallel relation thereto, a sheet of insulating material between said layers and spaced therefrom by air gaps, means for projecting an image on said photoemissive layer and means for applying an accelerating electric field between said photoemissive layer and said conductive layer.

2. A device for developing and thereby rendering visible an electric charge image upon the surface of sheet material which comprises a chamber containing finely divided material and an agitator therein for bringing said material into suspension in the air of said chamber and means for supporting said sheet material across the top of said chamber with the charged surface thereof facing downwardly and in contact with the air suspension in said chamber.

3. The method of producing a permanent visible picture from an electrostatic image on the face of a member which comprises bringing finely divided electrostatically attractable material adjacent said face whereby to form an electrostatic deposit thereon, then engaging said face and deposit with a sheet of material having a thermosoftening adhesive surface and applying heat and pressure to the assembly.

4. The method of electrophotography which comprises placing a layer having an insulating surface in spaced parallel relation to a photoemissive layer, with an air space therebetween, applying an electron accelerating electric field across the air space between the photoemissive layer and said insulating surface, and projecting an image on said photoemissive layer whereby electrons will be emitted therefrom and drawn to said insulating surface by said field thereby producing an electrostatic latent image on said insulating surface, then depositing a finely divided material on said insulating surface to develop said image.

5. An electrophoto device comprising a photoemissive layer, a layer of insulating material and means supporting said insulating layer in spaced parallel relation to said photoemissive layer with an air gap therebetween, means for applying an electric field between said layers to drive electrons ejected from said photoemissive layer to said insulating layer, means for projecting radiation onto said photoemissive layer in an image to be reproduced, said radiation causing photoemission of electrons from said layer, means for depositing a finely divided material on said insulating layer, and means for moving said insulating layer into a position to receive said finely divided material.

6. A device for developing an electrostatic latent image on the surface of an insulating layer which comprises a chamber having one side open to the surface of said layer, an agitator for the air of said chamber and any powder particles carried thereby, means to support said insulating layer over the open side of said chamber, and means to move said layer along in a direction parallel to its own surface whereby successive portions of said surface may be brought over the open side of said chamber.

7. A device for developing an electrostatic latent image on an insulating sheet surface which comprises means for applying dust to said surface, means for heating the surface to soften any thermosoftening material on said dusted surface and fix said dust thereto, and means to move said surface along in a direction parallel to itself first past said dusting means and then past said heating means.

8. In combination, means for moving an insulating layer having an electrostatic charge image on its surface along in a direction parallel to its surface, means to apply dust to said surface, means to subsequently roll a sheet of flexible sheet material against said surface and means for applying heat to said sheet.

9. In combination, means for applying dust to the surface of an insulating layer, means

for subsequently rolling a sheet of flexible material against said surface and means for heating said sheet.

10. In combination, means for moving an insulating sheet along in a direction parallel to its surface, means for applying an electric charge image to said sheet, means for dusting said sheet and means for fixing the dust in the configuration in which it has been deposited, said three last named means being sequentially arranged along the path of movement of said insulating sheet in the order named.

11. In combination, means for moving an insulating sheet along in a direction parallel to its surface, means for applying an electric charge image to said sheet, means for dusting said sheet and means for rolling a flexible sheet against the dusted surface of said insulating sheet and for heating said flexible sheet, said three last named means being sequentially arranged along the path of movement of said insulating sheet in the order named.

CHESTER F. CARLSON.